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IN THE UNITED STATES DISTRICT COURT

FOR THE EASTERN DISTRICT OF CALIFORNIA

THE CALIFORNIA NATURAL RESOURCES AGENCY, ET AL. Plaintiffs, **v.** **GINA RAIMONDO, ET AL.,** Defendants.	Case No. 1:20-cv-00426-DAD-EPG **SUPPLEMENTAL DECLARATION OF BRUCE HERBOLD IN SUPPORT OF MOTION FOR INTERIM INJUNCTIVE RELIEF AND TEMPORARY STAY OF LITIGATION** Date: February 1, 2022 Time: 9:30 a.m. Dept: 5 Judge: The Honorable Dale A. Drozd Trial Date: TBD Action Filed: February 20, 2020

I, Bruce Herbold, Ph.D., declare as follows:

1. This declaration is intended to supplement my November 23 Declaration (ECF 224)[1] and is based on my review of a) the final Juvenile Production Estimate letter dated January 15 (Exhibit A); b) the declaration of Bradley Cavallo (Cavallo Decl.), which was submitted as evidence by Defendant-Intervenors; ECF 240; and c) the other evidence and arguments of Defendant-Intervenors. I also was present at the deposition of Mr. Cavallo by the State Plaintiffs.

2. On the basis of my review, I have concluded as follows:

I. The evidence submitted by Defendant-Intervenors, including the juvenile production letter and the evidence underlying the Cavallo Decl., support my conclusion that the survivability of several of our listed species is even more precarious than in 2020, when I submitted my previous declaration (ECF 54), given that there have been two more years of poor survival. The 2019 BiOps pose a severe threat to species that are at historically low abundance in an environment with multiple imminent threats to their survival, and the immediate implementation of the Interim Operations Plan is our most likely path to improving salmon and smelt survivability through September 30, 2022, during the re-initiation of consultation.

II. The Cavallo Decl. attempts to sow scientific discord where none exists regarding the 56-degree temperature for cold-water releases, introduces “red herrings” such as the amount of dissolved oxygen, thiamine deficiency, and density dependence, misstates the number of winter-run Chinook salmon (henceforth ‘winter-run’) that experienced temperature effects, and relies on outdated extinction risk data and unpublished data unavailable for peer review or analysis.

III. The Cavallo Decl. attempts to cast aspersions on the Martin model to return state and federal agencies to an outdated model. The Martin model is the primary tool of

[1] Where appropriate, I will draw from my own previous opinions, figures, and facts as necessary to respond to the evidence provided by Defendant-Intervenors, always citing my November 2021 declaration as “Herbold Decl.”

the Interagency Ecological Program's winter-run Chinook salmon Project Work Team that is charged with giving annual guidance to the National Marine Fisheries Service (NMFS).[2]

IV. Finally, the Cavallo Decl. overly relies on hatcheries and hatchery fish, notwithstanding the evidence that hatchery influence—which NMFS includes as a factor in extinction—appears to be increasing.

I. INTRODUCTION: KEY INDICATORS FOR SACRAMENTO RIVER SALMON

3. All scientists and managers who work with winter-run rely on four key indicators to check on the population: the abundance of returning adults to the spawning grounds (or "escapement"), the juvenile production index (JPI); the egg-to-fry survival (ETF); and the estimate of juvenile production entering the Delta (JPE). All four of these estimates have been calculated and used widely.

4. Winter-run are an excellent fish for monitoring. All adults spawn in the clear weather of summer in a relatively small area, mostly without much vegetation coverage. Adults scoop out large nests (redds) that are directly counted in aerial surveys. Salmon carcasses are tagged and allowed to move with water flows, and the fraction of tagged carcasses in the next count, compared to untagged bodies, allows an estimate of the total number of spawners. Carcass surveys also allow estimation of the sex ratio of spawners. All young salmon must pass Red Bluff Diversion Dam, so large traps there sample the entire population. Like almost all monitoring data,

[2] From its webpage (https://iep.ca.gov/Science-Synthesis-Service/Project-Work-Teams/Winter-run-Chinook-Salmon):

i. "The **Winter-run Chinook salmon Project Work Team** coordinates research, monitoring and management activities for the state and federally-listed endangered Sacramento River winter-run Chinook salmon. The PWT is composed of staff from the California Departments of Fish and Wildlife and Water Resources, Metropolitan Water District, National Marine Fisheries Service, Bureau of Reclamation, and the U.S. Fish and Wildlife Service and other stakeholders."

ii. "The team's objectives are:

1. "Facilitate communication and information exchange on technical issues among the agencies and stakeholders
2. Provide advice, peer review, and recommendations on technical issues related to the protection, restoration, and management of winter-run Chinook
3. Develop and submit an annual recommendation letter to the National Marine Fisheries Service for the calculation of the Winter Run Juvenile Production and Central Valley Project and State Water Project Take Estimates"

the numbers are estimates or indices with accompanying measures of uncertainty. The only consistent bias that I am aware of is that large flows can clog, damage, or move traps, so in wetter conditions more fish might be missed. However, USFWS applies accepted methodologies to estimate juvenile fish passing the traps when they are not operating. Fortunately, wetter conditions are almost always more supportive of migration and lead to better adult abundance.

5. The juvenile production index (JPI) is an estimate of the total number of juvenile salmon arriving at Red Bluff Diversion Dam, where large rotary screw traps catch and sample their abundance. The JPI is recalculated to fry production by multiplication by the survival rate from the spawning site to Red Bluff (survival rate is estimated by tracking tagged fish from the hatchery). The number of fry produced is then compared with the number of eggs estimated to have been laid (average fecundity multiplied by the number of females). The ratio of eggs laid to fry captured estimates how many eggs successfully hatched, the Egg-To Fry ratio (ETF). The ETF ratio is the best measure of the quality of spawning conditions each year. Note that the absolute number of juveniles is a function of how many adults came back in that year, but the ratio of spawners to young is purely an estimate of the spawning success and is independent of how many juveniles or adults are counted. The quality of spawning conditions is largely controlled by flows from the Shasta and Keswick dams and the temperature of the water released, both of which are largely controlled by dam operations. The ETF is used to assess how well Shasta Dam operations protect winter-run egg incubation. Modeling of spawning success under various operational scenarios allows better planning of dam operations.

6. Mr. Cavallo delves deeply into two other factors that can affect egg-to-fry survival: density dependence and thiamine deficiency syndrome. These and other factors are not directly addressed in the Martin model (Martin et al. 2017) that is used to assess the impacts of water flow and temperature on egg survival. Such factors as those raised by Mr. Cavallo can certainly affect egg survival, usually for the worse. The impacts of such factors are not explicitly addressed and are treated as unvarying constants in the Martin model, because they cannot usefully guide choices of dam operation scenarios. Planning, not predicting, is the primary use of the Martin model.

7. The Juvenile Production Estimate (JPE) reduces the JPI by an estimate of survival from Red Bluff Diversion Dam downstream to the I Street Bridge in Sacramento to yield an estimate of the number of fish entering the Delta and, so, at risk of entrainment. The JPE informs the loss thresholds that can require export restrictions under the Incidental Take Permit (ITP) for the State Water Project (and which are included in the IOP), as well as the annual loss thresholds in the 2019 NMFS BiOP.[3] Note that the loss thresholds only address the number of young salmon retrieved from the fish screens of the state and federal salvage facilities. As I stated at length in my earlier declaration the number of salmon 'salvaged' from the screens is a very small fraction of the number entrained off their migratory path by project operations.

8. The JPI and JPE are useful indices of how many young are produced each year. Both reflect the number of adults that returned and the number of eggs they laid and fertilized. High juvenile production can be because a lot of adults came back or because a lot of the young survived, or in perfect times, both. The number of adults is largely a function of river conditions three years earlier and ocean conditions in the three years since. Although Mr. Cavallo attempts to downplay its importance, egg-to-fry survival estimates are the best metric of spawning success each year and are independent of conditions three years earlier or intervening ocean conditions. Thus, the ETF ratio allows clear insight into the impacts on winter-run of weather and dam operations each year.

9. Mr. Cavallo relies on adult escapement numbers to reach conclusions about species status. This is problematic, because escapement numbers tell us about adult returns, but these numbers do not tell us the whole picture of what is going on with the species. Adult escapement tells us how winter-run production was three years ago, how those young did in the ocean, and how the surviving adults did on their migration through the Delta and up the river. Annual escapement doesn't address conditions in three years going forward and how that will affect their progeny. We must look at a timescale on the order of 5-6 years to say anything useful about how the species is doing, as is done by NMFS with their 5-year status review cycle.

[3] Mr. Cavallo erroneously states that the JPI, and not the JPE, informs a take limit. Cavallo at ¶ 27.

II. MR. CAVALLO'S OWN EVIDENCE CONTRADICTS HIS BIOLOGICAL CONCLUSIONS

10. First, 2021 ETF ratio shows that winter-run hatching success was poorer than the model output. Mr. Cavallo repeatedly attempts to reconcile two contradictory views: 1) that the Martin model that I used in my November 23 declaration is badly flawed and 2) that thiamine deficiency is the "main culprit" in the exceptionally poor survival to hatching in 2021, which Mr. Cavallo elsewhere characterizes as "relatively low." Cavallo at ¶ 46.

11. Although I do not agree with Mr. Cavallo that the Martin model is flawed, even Mr. Cavallo's corrections show that outcomes are better for winter-run at temperatures proposed in the IOP. During his deposition, Mr. Cavallo was asked about his revised table of the Martin model. Cavallo Decl., Fig. 9. Even with the additional uncertainty he insists should be built in, he estimated during the deposition that the range of temperature-dependent mortality for temperatures of 54 degrees at up to 73 percent mortality, for 55 degrees at up to 87 percent mortality, and of 56 degrees at up to 99 percent mortality. See Decl. of Flannery, Exh. 2 at 77:3-78:1; 78:22-79:8. Mr. Cavallo said that there would be no harm to winter-run at ranges contemplated by the IOP. While I disagree that the model needs to be adjusted in the way he describes, I do agree with Mr. Cavallo's findings that predict lower temperature-dependent mortality at 54 and 55 degrees, which are temperatures contemplated by the IOP.

12. I have recast Mr. Cavallo's Table 2 below to provide a broader context by including year types (Wet, Below Normal, Dry, and Critically Dry) and by inserting a column of the simple difference between the model results and the actual egg to fry survival each year. The Martin Model, using water temperature as its controlling parameter, predicted an exceptionally low egg survival rate of 5% in 2021.

Year (year type)	Actual ETF	Model	Difference between model and measured	Mr. Cavallo's "% deviation"
2016 (BN)	.24	.36	-.12	53
2017 (W!)	.49	.36	+.13	-25

2018 (BN)	.26	.34	-.12	30
2019 (W)	.18	.30	-.12	67
2020 (D)	.109	.26	-.17	139
2021 (C)	.026	.05	-.024	90

13. Mr. Cavallo's discussion of his table and of the declarations of myself and Dr. Rosenfield errs in several ways:

14. First, the purpose of the Martin model is to guide project operations in providing suitable temperatures for salmon spawning below the dam (temperature dependent mortality), not to predict actual survival rates. Other factors can affect actual egg survival, but the model only predicts the impacts of flow and temperature. When I compare model results with field data I usually just subtract one from the other to assess how different they are (called "residuals" by statisticians); that is what I have done here, and the simple differences tell a different story than the interpretation Mr. Cavallo makes. Despite its limited focus, the Martin model is consistently close to the actual ETF ratio. Although the actual ETF ratio varied widely from 49% to 2.6% in the last six years, the model was within 17% of actual in all years and was much closer in most years. This predictive success of the model implies that factors not modeled are not as impactful on ETF survival as temperature and flow. Interestingly, the model is generally conservative in relation to the actual, which would be expected since the model doesn't address everything that can affect ETF survival.

15. Secondly, Mr. Cavallo's Figure 4 provides a clear "primary culprit" to explain the conservative bias of the Martin model. Later-arriving salmon often disrupt the redds of earlier arrivals, killing the eggs of those early arrivals (called "redd superimposition"). Mr. Cavallo's Figure 4 clearly shows a sharp decline in ETF survival with abundance of female spawners, almost certainly a case of redd superimposition in the limited spawning area available for winter-run. The years of fewest female returns are 2017 and 2011 which are, by far, the years of greatest ETF survival. The only year in Table 2 when the actually observed level of ETF survival was higher than predicted by the Martin model was 2017. This suggests that some baseline level of

redd superimposition is included in the model constants and that extreme low female abundance pushed density dependence effects in 2017 below the assumed constant level. The range of ETF survival with increased spawner abundance goes from 20% to 32%; that 12% difference matches well with the 12-13% difference of the model ETF from actual shown in Table 2 based only on temperature data.

16. Thirdly, Mr. Cavallo places great emphasis on the emerging concern about thiamine deficiency, a problem that has been described for a number of fish and aquatic mammals around the world. Mr. Cavallo cites the winter-run Chinook salmon Project Work Team letter on the 2021 JPE;

> Thiamine concentrations in egg samples from 30 females spawned at LSNFH in 2021 showed 83 percent of females with thiamine low enough where some fry mortality would be expected (T. Lipscomb, USFWS pers. comm).

Cavallo Decl., ¶ 33.

This concern is so new and poorly understood that no scientific paper has yet been published on it with regard to winter-run. The quote from Mr. Lipscomb reports that 24 of the 30 females he examined had levels at which "some fry mortality could be expected." We have no idea what level of mortality might be reasonable to assume. Despite having no quantitative basis for the impacts of thiamine deficiency on winter-run egg survival, Mr. Cavallo concludes in the third bullet of his opening summary that "Lower than expected ETF survival in 2021 resulted from an uncertain combination of continued thiamine deficiency, high adult abundance, and elevated water temperatures…" The Martin Model, using only temperature data, predicted an ETF survival of 5% but the actual value measured was 2.6% (compared to values as recently as 2017 as high as 49%). Thus, flow and water temperature explain almost all of the reduced egg survival in 2021. In future years, thiamine may rise as an important parameter to consider, but in 2021 almost all the eggs laid were going to die due to the high temperatures across most of the spawning grounds, irrespective of what their mothers had eaten in the ocean.

17. Fourthly, Mr. Cavallo calculates a "% deviation" of the observed and predicted ETF ratios. This is a standard statistical tool for measuring the difference between one set of numbers and another. However, such calculations are fraught when applied to percentages (and especially

when it is just two numbers rather than two sets of numbers). The problem is nicely illustrated in the Table 2 where the two very small numbers, the smallest overall in fact, have a difference that is very small but a % deviation that is very large, because the difference between 5% and 2.6% is a misleadingly large 90% of that tiny 2.6%. By using percentages as data and using single numbers rather than two sets of data, Mr. Cavallo violates standard guidance on how to use his statistic and obscures the remarkable applicability of the Martin model.

III. MR. CAVALLO'S OWN EVIDENCE CONTRADICTS HIS OPINIONS ON THE STATUS OF THE SPECIES

18. Mr. Cavallo's first summary opinion is that "The winter-run Chinook salmon population has recovered fully from the population decline associated with the 2014-2015 drought." However, his own "Figure 1," reproduced below, shows that the fish are not fully recovered at all.

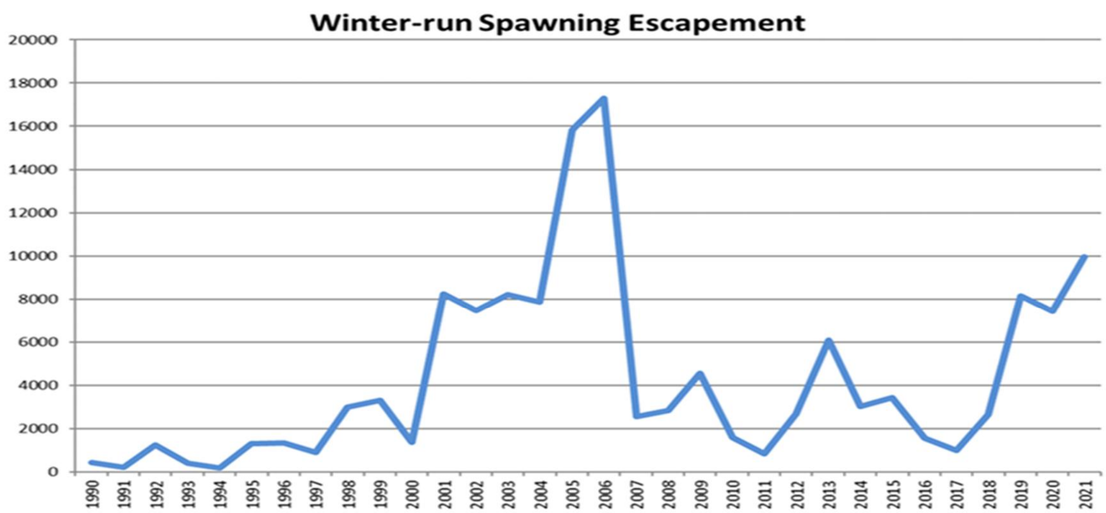

Figure 1. Sacramento River winter run Chinook spawning abundance 1990-2021 (Source: CDFW 2021c, CDFW 2021b).

19. The population consists, as Mr. Cavallo states, of three-year classes (with some 2- and 4-year-olds), meaning that adult abundance is largely limited by freshwater spawning, outmigration and ocean entry conditions three years prior. Cavallo Decl.,t ¶29. Even the simplest look at whether winter-run is "fully recovered" should compare recent three-year periods with abundance in the three years from 2004 to 2006. Figure 1 strongly shows that abundance of any

three years since 2007 is nowhere near what it was in the 2004-2006 period. Cavallo Decl., ¶ 25. Figure 1 also is unhelpful as an indicator of future recovery because spawning conditions in 2020 and 2021 were very poor, so returns in 2023 and 2024 are likely to be small. Herbold Decl., ¶29.

20. Some historical perspective is helpful. The plateau in recovery shown in the first four years of the 2001-2006 'recovery' of the population from its nadir in 1993/4 corresponds to a 2-year drought from 2001-02. Because Mr. Cavallo's Figure 1 begins in the 1990s, it fails to capture the fact that spawning population below Shasta Dam prior to 1976 regularly exceeded 20,000. Droughts in 2013-2015, below-normal water years in 2012 and 2016, and a drought from 2007-09 all precipitated large declines in adult abundance as shown in Figure 2 below. Cavallo Decl., ¶ 29. A longer historic perspective puts even the early-2000s high numbers in perspective.

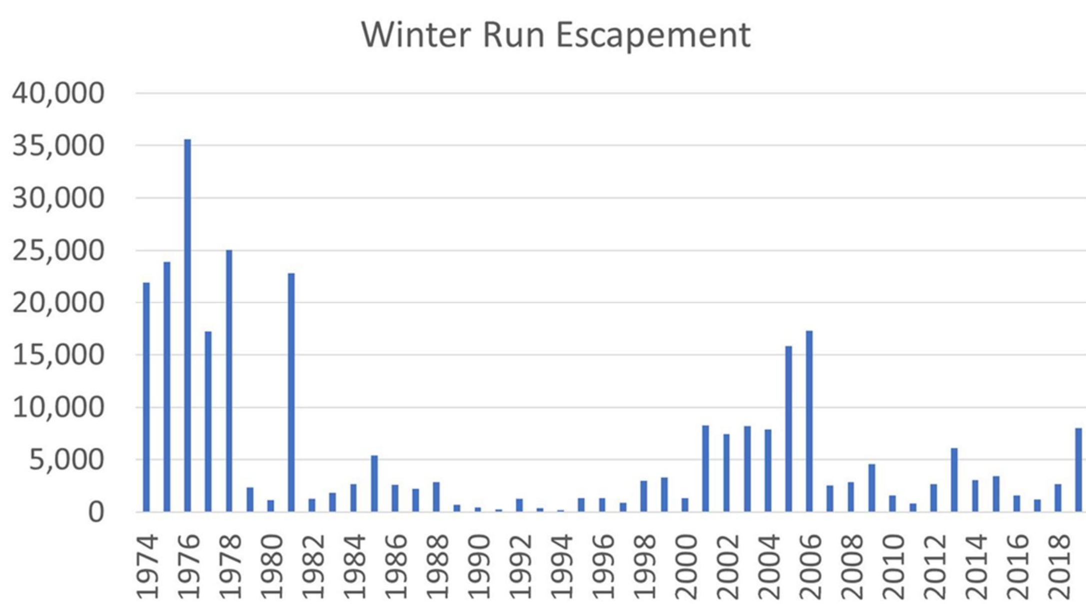

Figure 2: A longer historic perspective on adult abundance

21. The 2013-2015 drought (the usually cited span of that drought) included not only record-setting poor spawning conditions for salmon but also presented fish in the ocean with remarkably high temperatures and poor feeding opportunities. This led to record low returns of adults in 2016-2017. After the drought California experienced a series of years with higher water availability, including the wettest year on record. This allowed the small number of winter-run returning in those years to have high survival of their eggs and of out-migrating young. Ocean conditions had also returned to more supportive temperatures and food production. Thus, those

fish from the previous drought came back in good numbers into the current drought conditions, where they suffered in 2021 the lowest egg survival on record. A generation of salmon spans three years and it takes more than one generation to achieve anything that could be called recovery. Thus, Mr. Cavallo's statement of full recovery can only become true if the exceptionally wet conditions that followed the last drought return over the next three years.

22. Mr. Cavallo also claims (in his fourth summary bullet) that "[t]he three abundance-related criteria for extinction risk are likely to remain low when juveniles from the 2020-2021 brood years return as adults in 2023-2024." Cavallo Decl.,¶6. At paragraph 39, Mr. Cavallo discusses extinction risk analysis in "the most recent five-year review" conducted in 2015 for winter-run. Data used in that status review mostly pre-dated the low survival of winter-run during the 2014-2016 drought. Mr. Cavallo must be aware of the age of the data—and of the more recent NMFS publications and action plans spotlighting the high levels of concern about this species that suggest a very different conclusion about the extinction risk for this species.

23. In the last five years California has had its wettest year, its hottest year, and its second driest year, so in the next status review I expect NMFS to take a more wary view of climate change impacts than it did in 2015. If 2022 has spawning conditions as bad as 2021, after the poor production in 2020, then we will have three generations at risk, which risks the survivability and recovery of the species. Taking a precautionary approach in the face of our recent change in climate and its risk to salmon is the only sensible way to protect the species. Whatever the quantified impacts of thiamine deficiency turn out to be on salmon, clearly the species is facing a new and as yet unaccounted for stressor. I do not share Mr. Cavallo's sanguine sense of the future of winter-run Chinook salmon.

24. Pointing to the JPI, Mr. Cavallo opines that "winter-run production in 2021 was higher than production observed during the 2014-2017 period." Cavallo Decl. at ¶ 6. More pertinently, 2021 was the fifth time in the last 20 years when production was below 1 million; 2021 production only got as high as it did by the fortuitous return of the third highest number of female spawners in the last 20 years.

25. The most telling and damning aspect of the 2021 experience is that ETF survival was the poorest on record. ETF survival is, in most years, the critical stage in the life of winter-run and the one under our most direct control. After losing temperature control in 2014-15, many meetings and plans were made to avoid putting the fish at such extreme risk again. Unfortunately, the key to effective temperature management is retention of suitable carryover storage from year to year behind Shasta Dam. The new 2019 Biological Opinions removed any requirement for carryover storage and instead based temperature management plans on whatever storage was available at the end of April. Thus, temperature management options were greatly reduced and in 2021 adequate temperatures were not maintained for much of the spawning of winter-run and Spring run Chinook salmon. The fact that we could do even worse at protecting winter-run spawning in 2021, after concerted efforts to avoid a repetition of the record-setting mortality of winter run eggs in 2014-15, fuels concern that the wild winter-run population is at risk of extinction.

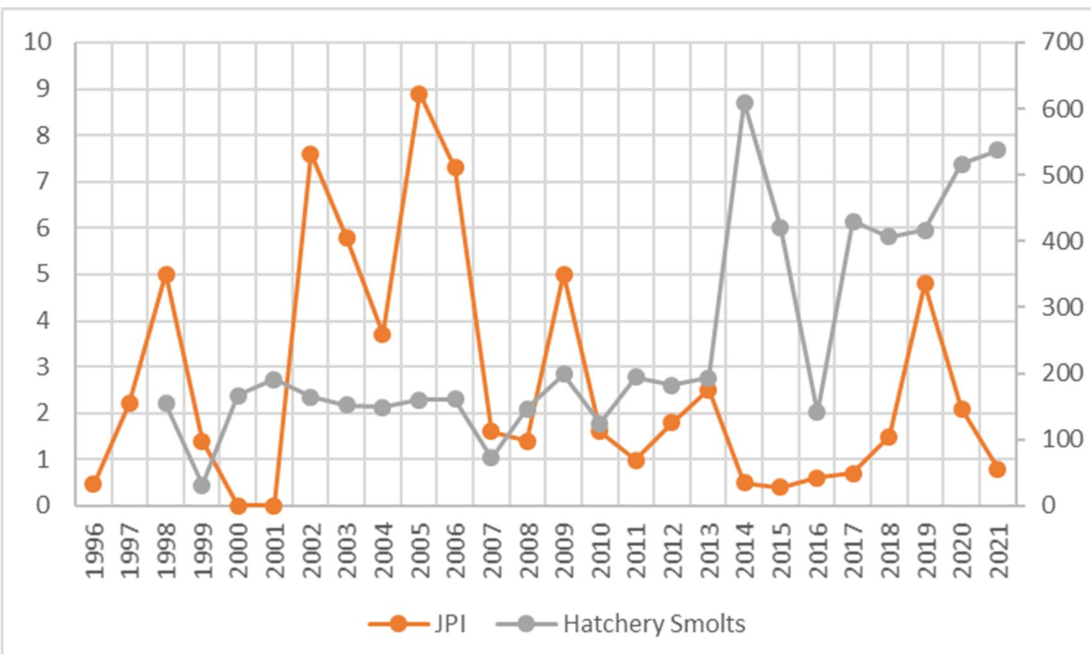

Figure 3: Trends though time of wild produced fry as estimated by JPI in millions vs. hatchery released smolts in thousands

26. Mr. Cavallo criticizes my and Dr. Rosenfeld's' declarations for paying inadequate attention to the role of the Livingston Stone National Fish Hatchery that runs two parallel programs to support winter-run. Most of the returning winter-run were hatchery derived, which

Mr. Cavallo notes, but he again neglects to provide key scientific context. Cavallo Decl. at ¶ 30. The hatchery does a good job and has proven essential to get us through some of the binds we have been in recent years, but hatchery fish generally perform poorly in the wild. The massive releases of hatchery raised fish were a large part of the numbers that came back after the 2013-15 drought, but by 2018 wild fish made up more than half of the returnees, thus demonstrating the superior survivability of wild-spawned fish in the wild. The interbreeding of hatchery fish with wild populations is known to reduce the resilience and viability of the wild populations. Herbold Decl. at ¶ 12. Declining wild winter-run production, coupled with a rapidly rising rate of hatchery releases (as shown in Figure 3, above, based on table 1 in Cavallo), causes me concern for the survivability of the species.

27. Just as adult escapement figures provide a window into the past, ETF numbers offer a preview of the future. For example, juvenile survival in 2014 was very poor, so there were very few wild adults returning three years later to make juveniles—producing an "echo" of low abundance. Although that low level of returning adults in 2017 couldn't produce a lot of eggs, the high flows led to high survival of their young, so lots of adults returned in 2020. In turn, ETF survival in 2020 was lower than all other years since 2003 except for 2014 and 2015 and led to a low JPI. As discussed above, the recent JPIs are only as high as they are because of the large number of adults coming back from the wet period of 2017-19. The recent ETF survival better reflects the more recent poor spawning/hatching conditions under the 2019 BiOps and is reflected in a steep drop off in both the model and estimate values in Mr. Cavallo's Table 2.

28. The spawning conditions that the 2020 and 2021 broodstock adults face on their return may determine the viability of the winter-run population. Poor adult abundance can be compensated for by good survival of their young; to a lesser extent, a large adult population can compensate for poor young survival.

29. Based on the egg-to-fry and juvenile production numbers reported in the draft JPE letter from the winter-run Chinook salmon Project Work Team and cited by Mr. Cavallo, as well as my review of the final letter (Exhibit A), the species is at a critical turning point. If 2022 has poor juvenile survival, we will have set up three successive years of poor adult returns in 2023-

2025. If those three years, in turn, have poor juvenile survival rates like the last three, the species will be in imminent danger of extinction.

30. Mr. Cavallo states that the viability of the spring-run Chinook Evolutionarily Significant Unit (ESU) was adversely influenced by the 2014-2015 drought. Deer and Mill Creek populations have still not recovered, and Butte Creek spring-run suffered very high pre-spawning mortality in 2021. Deer and Mill creeks are still accessible by spring-run but get their water from Mt. Lassen springs and snowmelt; in recent years the high temps and low snow levels have hurt them hard as spawning (and holding) grounds. However, Shasta operations do affect survival of Deer and Mill spring run juveniles as they migrate through the Sacramento River. There are numerous studies showing this, including data and models developed and used by Mr. Cavallo and his colleagues.

31. Before California's rivers and streams were dammed in the middle years of the last century, Spring-run Chinook were the most widely distributed and abundant run of the prodigious Central Valley Chinook salmon stocks. Deer and Mill creeks are small streams and would never have supported large populations; their less-blocked conditions allowed them to retain value to spring-run. Unless we get spring-run above dams on larger streams or manage them actively as with the San Joaquin introduction, the small streams they are now restricted to put them at greater risk than they would have experienced in the pre-dam period. They have limited access to suitable habitat and very limited opportunities for re-colonization into small streams like Deer and Mill after poor years. Ensuring sufficient flows of good temperature to support outmigration conditions from their few remaining sites is one way to compensate for the impact of dams on all of the spring-run's former habitats.

32. Mr. Cavallo's opinions and data imply that protecting the spring-run that make it to the Sacramento River is more critical to the survivability and protection of the species than usual. Because population resilience hinges on having a diversity of timing and life history strategies, we must protect them in all of their habitats and ages. Different life stages thrive differently in different year types. The life stage outmigrants that return as adults are not necessarily the ones that are most abundant as young. Shasta operations may not be a part of spring-run recovery but

they are an aspect of their survival that we can control to reduce their risk of extinction. The involvement of the resource and regulatory agencies in operational planning will allow for creative collaboration in managing this species in the immediate future, just as it will for winter-run. Herbold Decl. at ¶ 37.

33. As I previously stated, the consultation of the resource agencies with all the regulatory agencies, as described in the IOP, is a new and remarkably strong collaborative effort to meet the needs of winter-run in this coming crucial year, and the water temperature targets in the IOP better match the physiological needs of winter-run than the 2019 BiOps. Continued reliance upon the 2019 BiOps reduces the planning opportunities and the options available to keep winter-run from the serious threat of extinction while new Biological Opinions using the massive amount of new science, are written. Herbold Decl. at ¶ 37.

IV. THE CAVALLO DECLARATION ATTEMPTS TO CREATE SCIENTIFIC CONTROVERSY WHERE NONE EXISTS

A. There Is no Scientific Controversy Regarding 56 Degrees

34. Mr. Cavallo attempts to sow controversy regarding the 56-degree threshold, but his theories regarding temperature rely on outdated science applied in the USFWS temperature model that preceded the current, Martin model. Cavallo, ¶ 17. The 1999 USFWS report preferred by Mr. Cavallo is no longer the paper that is discussed in temperature management conversations but was the gold standard prior to Martin et al 2017. It was used as the basis for Water Rights Order 90-5 and the 56-degree target. The 1999 report is based on studies done in a hatchery in which temperature was a treatment, but all other variables (flow, dissolved oxygen) were held constant and at optimal levels. They did not vary temperature within each treatment. As a result, there is skepticism now about the validity of a 56-degree temperature target because it is the "best case scenario," given that the other key variables were optimal.

35. This is why the scientific focus has shifted to Martin et al. 2017, which is founded on a more realistic scenario. Martin et al. looked at key factors involved in survival (temperature, flow and DO) to better understand the mechanism behind survival. Eggs need oxygen while in the redd (gravel nest). Oxygen exchange is a function of temperature control and flow. Temperature

can be controlled and thereby oxygen exchange through the eggs, supported. If flows are high, then slightly higher temperatures can be tolerated. In the end, the message of both studies is the same—temperature affects survival and is the best variable to manage. The Martin model is quite effective as a tool to assess the effects of different dam operations, rather than to predict the interactions of temperature with all the other factors and assumptions that might affect the number of number of juveniles. The fact that its predictions have been so successful reinforces its value in guiding project operations and limits the likely import of the factors it does not address.

36. The differences between the two studies explain the reason why there is a 3-degree temperature difference between lab-based vs. field-based estimates. Martin et al. 2017 estimates 53.5 degrees, while USFWS estimates 56 degrees. It is also worth noting that 56 degrees is right at the threshold for known, exponential increase in temperature impacts on survival, which, from a management perspective, is not ideal. The huge impacts above 56 degrees, and the less-than-ideal conditions in the field, make Martin's lower target more appropriate.

37. In his effort to discredit the Martin model, Mr. Cavallo provides egg-to-fry ranges below 54.5 degrees and egg-to-fry ranges above 56.5 degrees, and then goes on to say the USFWS paper is not in conflict because we do not have any actual data at 56 degrees. This attempt to sow doubt due to lack of information is misleading and should not inform decisions regarding the management of fish.

38. As the science stands now, we have lots of information that Chinook salmon are very different in different places, so there's been a justified push to know our Central Valley fish better rather than relying on physiological studies from elsewhere. As mentioned above, Mr. Cavallo's own Figure 9 supports lower temperature dependent mortality at 54 and 55 degrees Fahrenheit than at 56 degrees and above. Flannery Decl. at Exh. 2, 77:3-78:1; 78:22-79:8. We also have mountains of peer-reviewed, published literature that suggests 56 degrees is too warm. U.S. EPA, which NMFS relied on in the 2019 BiOps, suggests 55 degrees Fahrenheit 7 day, average daily maximum (7DADM) for salmon egg incubation and fry. Achieving this 7DADM requires some daily average temperatures in the 53-degree range. The 2019 BiOps themselves describe temperatures above 53.5 degrees as "lethal," and calls for "intervention measures" at

temperatures above 56 degrees. NMFS 2019 BiOp at p. 761; Flannery Decl. at Exh. 3 (Deposition Exh. 6).

39. The IOP provides for the Shasta Planning Group, which will provide the type of collaboration and checks that will help avoid the poor outcomes of the past. In 2014, all of Shasta's cold-water pool had been depleted by mid-way through the egg incubation season, and the majority of the winter-run eggs and fry died. In 2015, there was limited cold-water pool again, the managers agreed to try an elevated temperature regime that would last throughout the egg incubation period (57.5 degrees). This elevated temperature led to low ETF survival, low overall passage past Red Bluff Diversion Dam, low JPI, low JPE, and high temperature-dependent mortality. These failed efforts provide management guidance.

B. Dissolved Oxygen Does Not Predict Fish Impacts the Way that Temperature Does

40. To avoid tying survival to temperature impacts, Mr. Cavallo plays up the effects of dissolved oxygen (O2), while downplaying the effects of temperature, ignoring the well-established interplay of temperature, flow, and survival. Cavallo Decl., ¶ 17. Oxygen can become more important if higher temperatures raise metabolic rates to where the embryo is using O2 faster than it can take it in; the embryo is basically a ball that O2 has to disperse into. If the embryo uses up its supply of O2 faster than O2 can disperse into the middle of the ball, it no longer has enough O2 to survive, and the embryo dies. This mechanism has been documented even where O2 is at saturation, partly because at higher temperatures there is less total oxygen at saturation.

C. Mr. Cavallo's Thiamine Deficiency Opinions Are Neither Supported by Data, Nor by the Scientific Community

41. Mr. Cavallo's sweeping thiamine deficiency opinions are simply unsupported by data or by the scientific community, or even by his own declaration. Early in the declaration, Mr. Cavallo correctly states that thiamine deficiency had an "uncertain" impact on survival, a statement with which I agree as stated above. Cavallo Decl. at ¶ 6, Herbold Decl. at ¶ 29. However, he combines that unknown effect with the effect of high adult abundance—which increased juvenile production—and elevated water temperatures, to conclude that the causes of

the low survival are "uncertain." Combining these factors serves only to conceal the fact that the quality of adequate spawning habitat is primarily determined by the timing and amount of cold water released from Shasta Reservoir. Herbold Decl. at ¶ 28.

42. Mr. Cavallo also quotes the CDFW Juvenile Production Estimate Letter (JPE Letter) as stating, "Survival studies of untreated fish would be necessary to understand lower survival due to latent effects of thiamine deficiency," a statement with which I would also tend to agree. Cavallo at ¶32; JPE Letter at p. 6.

43. However, later in his declaration, Mr. Cavallo attributes poor survival to thiamine deficiency. Cavallo Decl at ¶31, 32, Table 2. By paragraph 35, Mr. Cavallo's opinion has become that thiamine deficiency is "the primary culprit" for low ETF survival—all without the benefit of peer review. This does not seem to be the common understanding among the fish agencies or the fish science community, nor is it even supported by the data Cavallo cites. For Table 2, the Martin model correctly predicted an order of magnitude decline in ETF survival. The model used no thiamine effect which suggests that the decline from two-digit survival to single digit survival was not driven by thiamine. Rather, ETF survival for the first four years in Table 2, all of which were wet or below normal, is remarkably stable and then drops substantially as the drought began in 2020. None of that is consistent with Mr. Cavallo's conclusion that thiamine deficiency is driving JPI.

44. Some fry mortality probably occurred as a result of thiamine deficiency, but there is no basis for thinking it is a main contributor. I understand that ongoing research is being conducted to better understand the relationship between thiamine deficiency and mortality, but results won't be available until summer 2022 at the earliest, so the evidentiary basis for Mr. Cavallo's statement is unclear. Mr. Cavallo himself even states, "The effects of thiamine deficiency on egg or early fry survival have not been studied." At this point, thiamine deficiency is something that is being evaluated.

45. Mr. Cavallo also states that thiamine deficiency effects "are expected to be more severe" in wild fish than in laboratories—a statement has no apparent basis, but that also seems at

odds with his assertion that temperature effects are more severe in the laboratory setting. Cavallo Decl. at ¶33 (thiamine); ¶15 (temperature).

D. 50% of Fish Were Not Spared Temperature Effects

46. Mr. Cavallo opines that "elevated water temperatures … occurred after approximately 50% of winter-run eggs had already hatched and emerged from the gravel. Cavallo Decl. at ¶ 35. However, that does not mean that the 50% were immune to later temperature effects, nor that 50% is a reasonable percentage of redds (nests) for the Shasta Dam temperature control operations to essentially abandon.

E. Entrainment Remains a Concern for All Species

47. Despite the unusual precipitation patterns in October through December last year, dry conditions are expected for the foreseeable future as winter-run young enter the Delta (where their peak abundance is usually in February). Low flows maximize the risk of salmon entrainment off their migratory path, with some small fraction of that number being salvaged at the export facilities. Outmigrants this year weathered high temperatures, low flows and thiamine deficiency of greater consequence to the survivability and recovery of the species than fish in earlier years. At his deposition, Mr. Cavallo stated that the 2019 BiOps analysis of Steelhead impacts was inadequate, a statement that I agree with as regards take of San Joaquin Steelhead, which increases by 232 % under the 2019 BiOps. Flannery Decl at Exh. 6, NMFS 2019 BiOp, Table 90, Page 510. The 2019 BiOps' annual and cumulative loss thresholds for winter-run do much less to protect them. The entrainment of both Longfin Smelt and Delta Smelt remains of grave concern because of the continued exceptionally low values for each, especially if dry conditions continue through their upcoming spawning and hatching seasons.

F. The Declaration Often Relies on Unpublished, Unverifiable Data

48. Mr. Cavallo repeatedly relies on unpublished, often irrelevant data, which have not been made available for other scientists to review. In paragraphs 10 and 12, he states his opinion regarding spawning habitat gravels at various locations and bases his opinion on unpublished data not available for review. Cavallo Decl. at ¶ 10, 12. It unclear how he collected and studied these gravels. Unclear also is how data regarding Redding gravel are relevant to the suitability of the

IOP. In Table 2, there is no citation for the "USFWS" estimates. In Table 4, Mr. Cavallo omits data points that likely would alter the slope of the line and focuses on the mean value while ignoring the variability around the mean. In other tables, he focuses on variability as the reason why means cannot be relied upon. These inconsistencies are misleading.

49. At paragraph 61, Mr. Cavallo relies on a technical memorandum describing some supposed errors in the Martin model, which appear from the memorandum itself to have been fixed to the extent they were substantiated. See Cavallo Decl., Exh. D., p. 3 of 15. Again, this technical memorandum does not appear to have been peer-reviewed and seems an attempt to sow doubt regarding the model by reporting on side conversations between a Cramer Fish Science employee and NMFS.

V. THE MARTIN MODEL IS WIDELY USED AND WIDELY ACCEPTED

50. Mr. Cavallo devotes the lion's share of his declaration to discrediting the Martin model for overestimating temperature impacts on winter-run survival—while ignoring that the Martin model underestimated the amount of ETF mortality in 2021 and in five of the six years in his own Table 2.

51. The scientific evidence cited in support of his declaration seem to be Mr. Cavallo's own gravel studies, which are not peer-reviewed (see above), studies conducted on other rivers, and a 2020 lab study of physiology processes in the model.[4] Cavallo Decl. at ¶ 13. The relevance of this scientific information is unclear.

52. Mr. Cavallo's discussion of uncertainty reveals an apparent unawareness of both science and policy. There is always uncertainty in the constants estimated in a model. Uncertainty is inherent in science and management and is an ongoing consideration in management of endangered species. Models do not exist to predict the future, but to assess different possible futures. Importantly, any "serious problems that have not previously been disclosed or considered" appear to have been addressed by NMFS, so it appears Mr. Cavallo's main problem

[4] The 2020 study doesn't change the model, so the 2017 article is still the latest article on the Martin model.

is that the model is a tool used to make management decisions regarding water temperature and fish mortality.

53. Mr. Cavallo's Figure 9 states that the Martin model "cannot distinguish critical differences between 52 degrees and 56 degrees." Cavallo at ¶ 68. However, his deposition testimony indicated that the model showed a range of potential temperature-dependent mortality that rises to 99 percent at above 56 degrees. Flannery Decl at Exh. 2, 78:22-79:8. Thus, what this figure indicates to me is that a reasonably cautious endangered species program would not manage to a temperature of 57 degrees, but instead would target lower, achievable temperatures without the potential for near-total temperature-dependent mortality at 56 degrees. Given the constraints in managing the cold-water pool and the need to balance other uses, management should find a middle ground that is still scientifically supported. This supports the risk-averse approach of managing to the lowest temperature feasible while acknowledging uncertainty exists. The uncertainty does not invalidate the concept of managing to lower temperatures to reduce mortality—a concept supported by decades of scientific thinking. In contrast, saying that the model can't distinguish between two numbers-- which his own testimony showed was not true—then implying that makes it acceptable to operate to the highest of the range, ignores decades of science and prudent management.

54. Mr. Cavallo's opinion regarding the Martin model is not accepted by most scientists, and in some cases contradicts Mr. Cavallo's other opinions. The Martin model is peer reviewed and undergoes frequent examination and updating and is the most accurate tool we have. It does not account for all parameters that affect spawning success, but it is not used that way. Rather, it is used to assess potential temperature effects from dam operations. In fact, the Martin model is applied in the 2019 BiOps, which Mr. Cavallo otherwise supports. See, e.g., Cavallo Decl at ¶ 6.

55. Overall, Mr. Cavallo's declaration is a highly unscientific way to critique a widely used and helpful model. If the data didn't match with the predictions reasonably, then such a critique would bear discussion. But as discussed above, it does remarkably well. The assumptions he attacks here are the ones that most scientists would recognize cannot be exactly correct, but

which do not appear to introduce any bias into the results. That the field data are not "known precisely without error" is true of all field data.

VI. CAVALLO'S ASSESSMENT OVERLY RELIES ON HATCHERY FISH

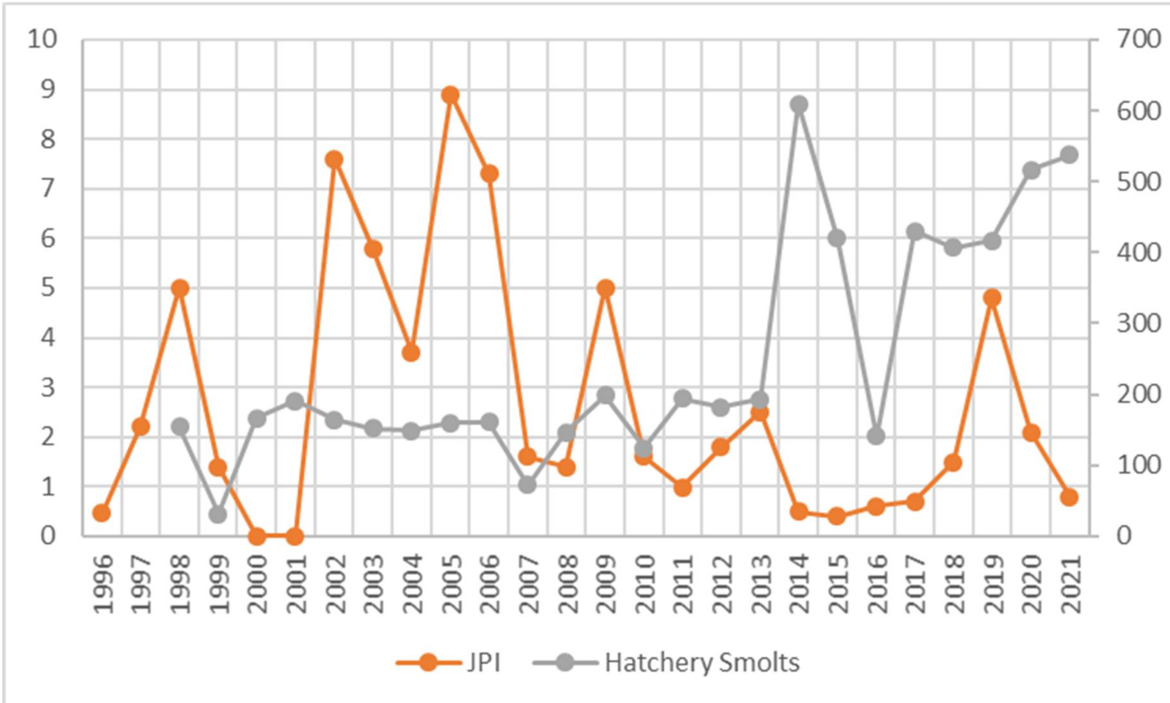

Figure 3: Trends though time of wild produced fry as estimated by JPI in millions vs hatchery released smolts in thousands

56. Mr. Cavallo's discussion of fish hatcheries is ultimately irrelevant to the IOP. Cavallo Decl. at ¶ 21. Although the conservation hatchery is a useful tool that was critically important in getting winter-run through the horrendous 2014-15 years, hatcheries cannot substitute for wild populations because they inherently select for fish that survive rearing in a hatchery, and this is a different genetic subset of young than the ones that do well in the wild. But the fact that wild spawned adults dominated returns three years later suggested to many scientists that wild-spawned fish survive better in the wild. Cavallo Decl., ¶ 30.

57. Using hatchery fish always comes with a cost, which is why hatchery influence is an important aspect of NMFS' analyses. Cavallo at ¶ 40. Neither Mr. Cavallo nor I appear to find that influence to be waning in recent years.

VII. CONCLUSION

58. My professional and expert opinion, as stated previously, is still that the Interim Operations Plan is substantially more protective of listed salmon and smelt species than the 2019 BiOps. California weather over the next nine months cannot be known, but we have fish survival rates at historically low levels and great uncertainty about how much water we will have available in May. The extremely low ETF survival in the last two years of both winter-run and the very poor production of young spring-run makes the success of the 2022 spawning season crucial in the survivability of both taxa. The small volumes of water behind Shasta Dam requires the greatest care and collaboration in preparing for the remainder of water year 2022. The 2019 BiOps are unclear and ineffective and leave key decision making solely in the hands of Reclamation. As such, they pose a severe threat to species that are at historically low abundance in an environment with multiple imminent, interacting threats to their survival. I have hopes that scientifically sound and consistent BiOps to replace the ineffective and unclear current BiOps will provide guidance and protection in the long term. But the smelt and salmon populations need to survive the coming year. With little water in reserve and no assurance of what environmental and management challenges will hit them while they are down in 2022, the endangered species are closer to extinction than any of them have been since they were listed. The increasing augmentation of their populations with hatchery smolts is another risk to their continued survival. The Interim Operations Plan is a reasonable and flexible plan, with involvement of all the responsible agencies, and with oversight and final approval resting with the appropriate regulatory agencies. I believe its immediate implementation is our most likely path to helping our listed salmon and smelts survive.

I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

Executed this 24th day of January 2022, at Oakland, California.

Bruce Herbold, Ph.D.

Exhibit A

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
650 Capitol Mall, Suite 5-100
Sacramento, California 95814-4700

January 20, 2022

Kristin White, Operations Manager
U.S. Department of the Interior
Bureau of Reclamation
Central Valley Operations
2800 Cottage Way
Sacramento, California 95825-1898

Electronic transmittal only

Dear Ms. White:

This letter provides the U.S. Bureau of Reclamation (Reclamation) with the estimated number of juvenile Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) from brood year (BY) 2021 expected to enter the Sacramento-San Joaquin Delta (Delta) during water year (WY) 2022. This juvenile production estimate (JPE) is provided by NOAA's National Marine Fisheries Service (NMFS) pursuant to the October 21, 2019, biological opinion for the reinitiation of consultation on the long-term operations of the Central Valley Project (CVP) and the State Water Project (SWP, NMFS 2019). The JPE is calculated annually and is used to determine the authorized level of incidental take for winter-run Chinook salmon, under Section 7 of the Endangered Species Act (ESA), while operating the CVP/SWP Delta pumping facilities in a given water year (NMFS 2019).

The authorized incidental take limits for natural origin winter-run Chinook salmon and hatchery winter-run Chinook salmon have been established in Table 140 in NMFS (2019) as follows:

- Loss of natural winter-run Chinook salmon is 1.3% of the JPE on a three-year rolling average or 2.0% of the JPE in any single year.
- Loss of Sacramento River hatchery winter-run Chinook salmon is 0.8% of the estimated hatchery JPE (fish surviving to the Delta) from Livingston Stone National Fish Hatchery (LSNFH) released into the upper Sacramento River on a three-year rolling average or 1.0% of the JPE in any single year.
- Loss of Battle Creek hatchery winter-run Chinook salmon is 0.8% of the estimated hatchery JPE (fish surviving to the Delta) from LNSFH released into Battle Creek on a three-year rolling average or 1.0% of the JPE in any single year.

The winter-run Chinook salmon JPE for BY 2021 is **125,038 natural-origin juvenile winter-run Chinook salmon expected to enter the Delta during WY 2022**. The incidental take limits for natural origin winter-run Chinook salmon are 1,625 (1.3% of 125,038) on a three-year rolling

average loss and 2,501 (2% of 125,038) for single year loss during WY 2022. The JPE calculation is developed as a function of the estimated number of juveniles passing RBDD and fry-to-smolt survival rates. Although adult escapement increased in 2021 to 10,269 compared to 6,390 in 2020, there was a significant decrease in the JPE for BY 2021 due to a decrease in egg-to-fry survival (2.6% this year compared to 11.5% last year).

The incidental take limit for hatchery-origin winter-run Chinook salmon is set separately for each release (*i.e.,* Sacramento River and Battle Creek releases). Based on projected releases, the **JPE for BY 2021 hatchery-produced (adipose fin-clipped) winter-run Chinook salmon juveniles released from LSNFH into the Sacramento River is 151,544** (estimated release of 537,771 juveniles). The incidental take limit for hatchery-produced winter-run Chinook salmon juveniles released from LSNFH into the Sacramento River is 1,212 (0.8% of 151,544) on a three-year rolling average loss and 1,515 (1% of 151,544) for single year loss during WY 2022. The **JPE for BY 2021 hatchery-produced (adipose fin clipped and left ventral fin clipped) winter-run Chinook salmon juveniles released from LSNFH into Battle Creek is 7,311** (estimated release of 139,000 juveniles). The incidental take limit for hatchery-produced winter-run Chinook salmon juveniles released from LSNFH into Battle Creek is 58 (0.8% of 7,311) on a three-year rolling average annual loss and 73 (1% of 7,311) for single year loss during WY 2022**.**

Status of Winter-Run Chinook Salmon

Juvenile winter-run Chinook salmon experienced very low survival in 2014 and 2015 due to drought conditions causing unfavorable temperatures in the spawning grounds. The California Department of Fish and Wildlife (CDFW), NMFS and the U.S. Fish and Wildlife Service (USFWS) responded to this crisis in part by reinstating the winter-run Chinook salmon Captive Broodstock Program at LSNFH. The primary purpose of the Captive Broodstock Program is to maintain a refugial population of winter-run Chinook salmon in a safe and secure environment to be available for use as hatchery broodstock in the event of a catastrophic decline in abundance. A secondary purpose of the program is to provide fish, when possible, to fulfill multi-agency efforts to reintroduce winter-run Chinook salmon into the restored habitats of Battle Creek and above Shasta Dam. Approximately 1,000 juvenile winter-run Chinook salmon propagated at LSNFH have been retained annually for the Captive Broodstock Program since it was reinstated beginning with BY 2014 (with the exception of BY 2016, when approximately 534 juveniles were retained).

Similar to BY 2020, BY 2021 was affected by a thiamine deficiency in returning adults, which transferred to low thiamine in their eggs, and resulted in a decreased number of successful fry upstream of RBDD. BY 2021 was also subject to low flows and low turbidity due to limited precipitation events. Outmigrating juveniles will also likely encounter challenging water conditions in certain areas where high debris from wildland fires in 2021 will travel into streams and rivers. Approximately 570,000 BY 2021 juvenile winter-run Chinook salmon were estimated to pass RBDD in BY 2021, compared to 2.1 million juveniles from BY 2020.

JPE Development Process

The process for developing the BY 2021 JPE was similar to what was done for BY 2020. A technical team from the Interagency Ecological Program (IEP), the Winter-run Project Work Team (WRPWT), met in December 2021 and January 2022, and provided recommendations to NMFS and CDFW (Enclosure 2) on January 14, 2022. The method used to calculate the BY 2021 JPE is derived from the USFWS' estimated number of juveniles passing RBDD. This estimate is known as the Juvenile Production Index (JPI) and is based on fry-equivalents at RBDD.

NMFS (2019) defines the JPE as the estimated number of juvenile winter-run Chinook salmon to enter the Delta (*i.e.,* Tower Bridge in Sacramento), but not through the Delta. The calculation of the winter-run Chinook salmon JPE for BY 2021 begins with estimates of winter-run Chinook salmon adult escapement in 2021, which are derived from carcass surveys conducted in the upper Sacramento River by CDFW. Escapement information was provided to NMFS via a November 15, 2021, letter (Enclosure 1). The CDFW estimate for total adult winter-run Chinook salmon escapement in 2021 was 10,269 spawners[1]. Of this total number of spawners, 313 were collected at the Keswick Dam trap site for spawning at LSNFH, leaving an estimated 9,956 to spawn naturally in-river. An estimated 5,860 of these spawners were females.

The number of adult spawners in 2021 was the highest in the past 10 years (Figure 1). The cohort replacement rate (CRR), which is a measure of the population's growth rate, was positive again this year (*i.e.,* 3.89), meaning the population is currently replacing itself (Figure 2), however, the trend is heading towards a negative growth rate.

Similar to BY 2020, genetic analyses were conducted on some length-at-date (LAD) juvenile spring-run Chinook salmon sampled from the RBDD RSTs, and the estimate of juvenile winter-run Chinook salmon emigration past RBDD was adjusted to include the LAD spring-run Chinook salmon that were determined to be genetic winter-run Chinook salmon.

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[1] The methodology used by CDFW (*i.e.*, Cormack-Jolly-Seber Model) to estimate escapement is the same model that has been used since 2012.

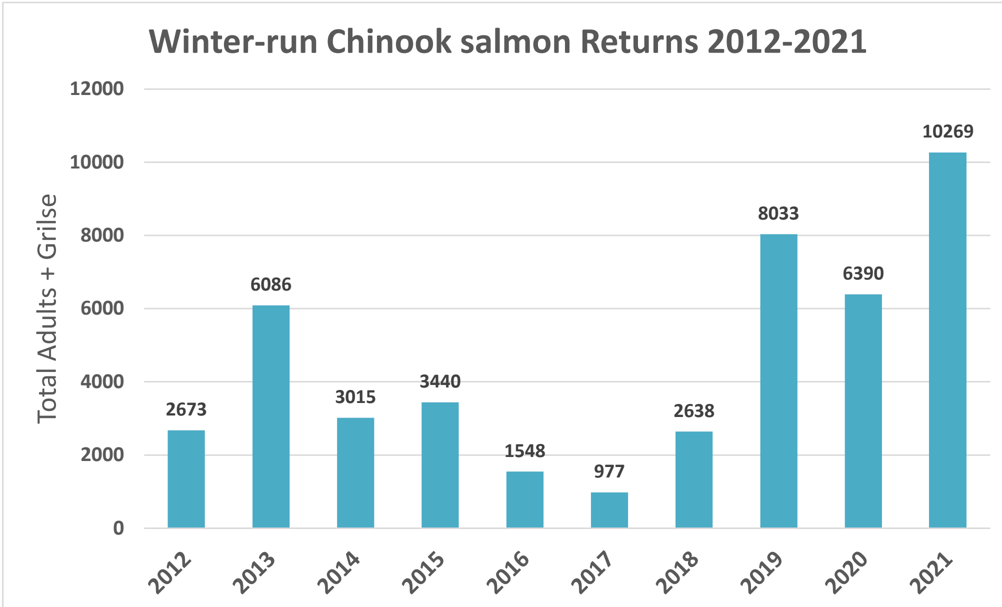

Figure 1. Winter-run Chinook Salmon Spawning Escapement 2012-2021 (CDFW 2021 and Enclosure 1).

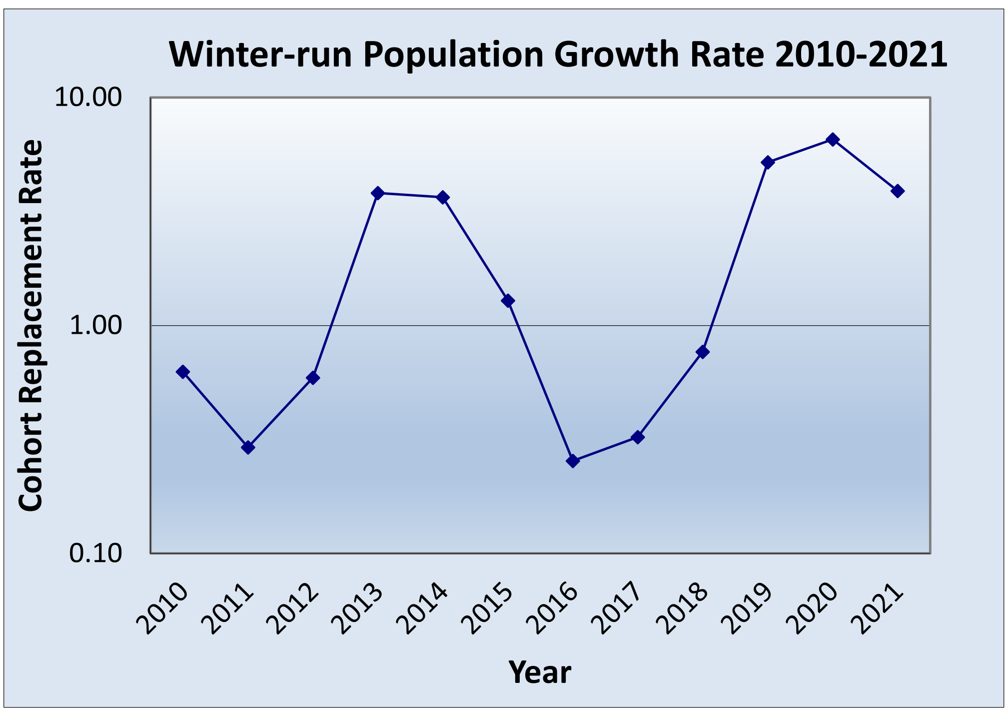

Figure 2. Cohort replacement rate for winter-run Chinook salmon 2010–2021 (CDFW 2021).

The JPE for BY 2021 incorporates the recommendations from the WRPWT (Enclosure 2). The WRPWT identified four factors in calculating the JPE, similar to last year, that it advises continuing for BY 2021:

1. Estimated number of fry passing the RBDD
2. Survival rate of natural-origin fry to smolts
3. Survival rate of smolts from RBDD to Delta entry (defined as Sacramento at the Tower Bridge)
4. Estimated survival rate of winter-run Chinook salmon hatchery fish to be released in February 2022

Estimates of egg-to-fry survival rate are based on the JPI estimate at RBDD. The JPI method is considered a more accurate estimate of the egg-to-fry survival rate because it is an annual estimate, which better represents the response of fish to the environmental conditions at the time of spawning (see recommendations from the WRPWT in Enclosure 2).

Another reason to use the JPI, rather than historical measures of egg-to-fry survival, is that the JPI approach may at least partially account for the potentially lower than average egg-to-fry survival that may be occurring in naturally spawned winter-run Chinook salmon due to issues related to thiamine deficiency in returning spawners. Any thiamine deficiency impacts manifested in egg viability or early fry stages will lead to a reduced JPI compared to what would have been observed absent thiamine deficiency impacts. USFWS has only one observation of abnormal fry behavior at the RBDD rotary screw traps, suggesting that any mortality caused by thiamine deficiency occurred primarily upstream of RBDD, though there may be latent impacts to young-of-year winter-run Chinook salmon downstream of RBDD that are not estimable based on information available this year. The assumption that most mortality would occur in early life history stages is consistent with observations at Central Valley hatcheries, where mortality and behavioral abnormalities associated with thiamine deficiency were documented soon after hatch.

The egg-to-fry survival rate has ranged from 2.56 percent to 49 percent from BY 2005 to BY 2021, with an average of 22 percent (see Figure 3). BY 2021 egg-to-fry survival rate is estimated at 2.56 percent. This low survival rate is likely largely due to thiamine deficiency and temperature-related mortality during egg incubation.

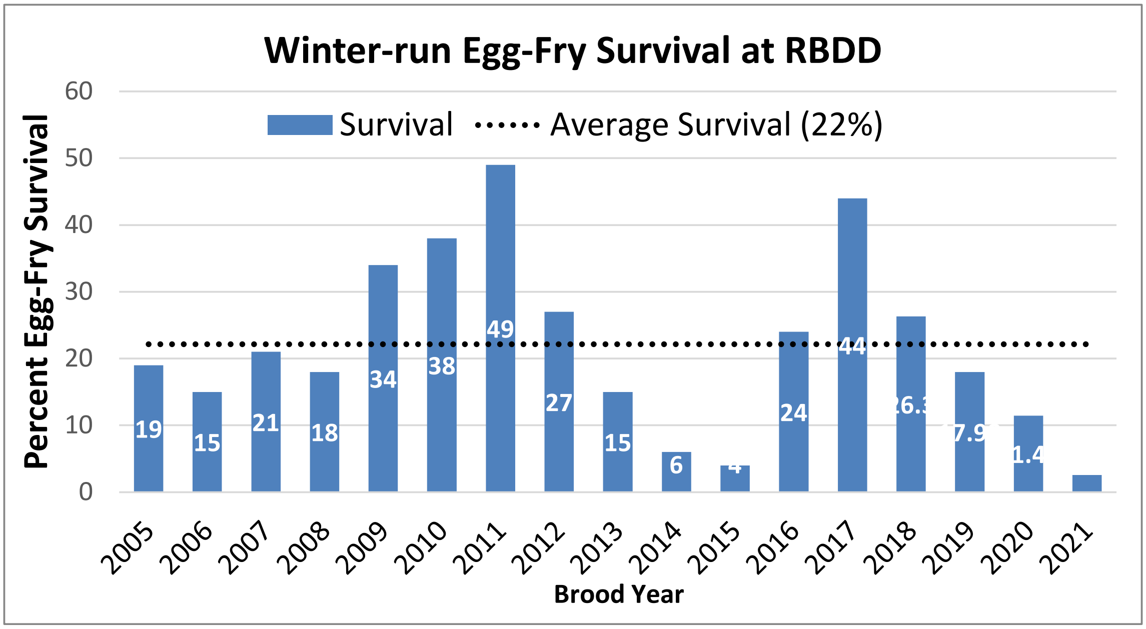

Figure 3. Winter-run egg-to-fry survival estimated at Red Bluff Diversion Dam 2005-2021 (Poytress et al. 2014, Voss and Poytress 2020, and Enclosure 2)

The calculation of the JPE is based on assumed environmental conditions (*e.g.,* temperature, flows, and turbidity) in the Sacramento River. However, actual environmental conditions, which may occur after the JPE is calculated, may be different than those assumed in the calculation of the JPE. The WRPWT recommends the fry-to-smolt survival rate forecasting method developed by O'Farrell et al. (2018), which uses recent winter-run Chinook salmon survival data and is updated with new survival data annually. The WRPWT also recommends the smolt survival to the Delta calculation based on a weighted average of acoustically-tagged hatchery winter-run Chinook salmon releases from RBDD to the Tower Bridge (in Sacramento). NMFS considers the Tower Bridge as the point of Delta entry.

Using the JPI, and based upon the WRPWT recommendation, NMFS estimates a JPE of **125,038 natural-origin juvenile winter-run Chinook salmon entering the Delta during WY 2022** (Table 1 in Enclosure 2). Juvenile winter-run Chinook salmon are expected to emigrate into the Delta from November 2021 through April 2022, based upon CDFW historical monitoring data at Knights Landing rotary screw traps.

In early 2022, approximately 537,771 juvenile winter-run Chinook salmon propagated at LSNFH will be released into the upper Sacramento River near Redding (Caldwell Park). A portion of the juvenile winter-run Chinook salmon from LSNFH may be acoustically-tagged (JSAT) to monitor their survival and movement downstream, some of which may be released up to 30 days prior to the production release. The objective of the early tag release is to use this information to parameterize the JPE equation of survival versus holding time upstream in the river. All hatchery-produced winter-run Chinook salmon will be coded-wire tagged and marked (100 percent) with an adipose fin-clip before release so that they can be identified from other hatchery fish. Since the hatchery winter-run Chinook salmon have not been released yet, their survival rate is unknown.

Based on the WRPWT advice (Enclosure 2), NMFS used a weighted mean survival rate (*i.e.,* 0.2828) of the hatchery acoustic tag releases between Caldwell Park in Redding and the Tower Bridge in Sacramento to estimate how many hatchery fish released in the Sacramento River would enter the Delta. The survival rate for hatchery-origin fish is different than the natural-origin fish because it is measured over a longer distance (Caldwell Park vs RBDD). NMFS estimates that approximately **151,544 juvenile winter-run Chinook salmon from BY 2021 released into the Sacramento River from LSNFH will survive to enter the Delta during WY 2022**.

In 2017, the first group of winter-run Chinook salmon captive broodstock withheld and maintained at LSNFH reached maturity and became ready to spawn. Given the precarious status of winter-run Chinook salmon resulting from numerous years of drought, CDFW, NMFS, and USFWS determined that the progeny from captive broodstock could be used to "jump start" the Battle Creek Winter-Run Chinook Salmon Reintroduction Plan. The reintroduction of winter-run Chinook salmon to Battle Creek is an extremely important step in the conservation of this endangered species, highlighted by the fact that only a single population exists today. The progeny of the captive broodstock proposed for release into Battle Creek will be the fourth year that juvenile winter-run Chinook salmon will experience portions of Battle Creek that were recently restored, providing a unique opportunity to learn vital information about release strategies, marking and tagging regimes, habitat use, and survival.

Based on the WRPWT advice (Enclosure 2), NMFS used the weighted mean survival (*i.e.,* 0.0526) to estimate how many hatchery winter-run Chinook salmon released into Battle Creek would enter the Delta. In spring of 2022, approximately 139,000 juvenile winter-run Chinook salmon will be released into Battle Creek. This year, a subset of the winter-run Chinook salmon released in Battle Creek during WY 2022 may receive acoustic tags, allowing for the estimation of survival rates specific to releases occurring in Battle Creek. As releases of acoustically-tagged winter-run Chinook salmon continue during subsequent years, the data collected will allow for the refinement of the survival rates specific to Battle Creek and better estimates of the number of winter-run Chinook salmon released in Battle Creek that survive to the Delta. NMFS estimates that approximately **7,311 juvenile winter-run Chinook salmon from BY 2021 released into Battle Creek will survive to enter the Delta during WY 2022**.

Incidental Take Limits for Natural and Hatchery Juvenile Winter-Run Chinook Salmon

The authorized incidental take limit for the combined CVP/SWP Delta pumping facilities includes both the natural-origin (wild) and hatchery-produced juvenile winter-run Chinook salmon, as both are necessary components of the population for survival and recovery of the species. Incidental take limits are summarized below:

- For natural origin winter-run Chinook salmon: 1,625 on a three-year rolling average loss and 2,501 for single year loss.
- For hatchery-produced winter-run Chinook salmon juveniles released into the Sacramento River: 1,212 on a three-year rolling average loss and 1,515 for single year loss.

- For hatchery-produced winter-run Chinook salmon juveniles released into Battle Creek: 58 on a three-year rolling average annual loss and 73 for single year loss.

The JPE-related incidental take limits allow for errors in fish identification due to use of LAD criteria to determine Chinook salmon run (*i.e.,* differentiating from fall-run, late-fall-run, and spring-run Chinook salmon). The authorized level of incidental take for natural-origin winter-run Chinook salmon (*i.e.,* reported as loss at the CVP/SWP Delta fish facilities) under the ESA for the combined CVP/SWP Delta pumping facilities from October 1, 2021, through June 30, 2022, is for natural-origin winter-run-sized fish, based on LAD criteria.

The initial identification of naturally-produced (non-clipped) winter-run Chinook salmon at the CVP/SWP Delta fish facilities shall be based on the LAD criteria for the Delta. NMFS will continue to monitor fish salvage and loss, and loss densities of winter-run Chinook salmon and other ESA-listed species at the CVP/SWP Delta fish facilities, through participation in the Salmonid Monitoring Team technical team and the Water Operations Management Team.

NMFS acknowledges that additional research using acoustically-tagged winter-run Chinook salmon (both hatchery and wild) is necessary to provide a more robust estimate of in-reach survival of winter-run Chinook salmon in the Sacramento River and would also provide direct calculation of survival, thereby greatly improving the accuracy of the JPE. We recommend that funding continues for acoustic tag studies on winter-run Chinook salmon for BY 2022 and beyond to provide data on survival rates over a range of hydrologic conditions.

In closing, we look forward to continuing to work with Reclamation and the other State and Federal agencies to manage water resources in WY 2022 in a way that supports both water supply and fish and wildlife resources. If you have any questions regarding this correspondence, or if NMFS can provide further assistance, please contact Mr. Garwin Yip at (916) 930-3611, or via email at Garwin.Yip@noaa.gov.

Sincerely,

A. Catherine Marcinkevage

Cathy Marcinkevage
Assistant Regional Administrator
California Central Valley Office

Enclosures:

1. CDFW letter with winter-run escapement estimate for BY 2021, dated November 15, 2021
2. Winter-Run Project Work Team letter to NMFS, dated January 14, 2022

cc: Copy to file: ARN 151422SWR2006SA00268

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GAVIN C. NEWSOM, Governor
CHARLTON H. BONHAM, Director

November 15, 2021

Mr. Barry Thom
Regional Administrator, West Coast Region
National Marine Fisheries Service
1201 NE Lloyd Blvd., Suite 1100
Portland, OR 97232

WINTER-RUN CHINOOK SALMON ESCAPEMENT ESTIMATES FOR 2021

Dear Mr. Thom:

The California Department of Fish and Wildlife (CDFW) has developed Sacramento River winter-run Chinook Salmon escapement estimates for 2021. These estimates were developed from data collected in the Upper Sacramento River winter-run Chinook Salmon Escapement Survey (carcass survey) conducted by CDFW and U.S. Fish and Wildlife Service (USFWS) personnel.

Escapement estimates shown below were calculated using the Cormack-Jolly-Seber (CJS) mark-recapture population model:

Estimated Total In-river Escapement (hatchery and natural origin)	**9,956**
Estimated In-river Escapement (hatchery origin)	**3,030**
Estimated Number of In-river Spawning Females (hatchery and natural origin)	**5,860**

These estimates include only naturally spawning winter-run Chinook Salmon in the upper Sacramento River. An additional **298** winter-run Chinook Salmon were collected at the Keswick Dam trap site for spawning at Livingston Stone National Fish Hatchery. The total 2021 Sacramento River winter-run spawning escapement estimate, including in-river spawners and fish collected for hatchery broodstock, is **10,269** fish. The 90% confidence interval on this total escapement estimate is **9,280 to 11,258** fish.

The total escapement estimate includes spawned and unspawned carcasses from the winter-run carcass survey, ten female carcasses that were observed during the late-fall-run carcass survey earlier in the year, and five moribund fish collected for disease assay during the winter-run spawning season. Not included in these estimates are winter-run returns to Battle Creek into and upstream of the Coleman National Fish Hatchery as part of the Battle Creek “jumpstart” reintroduction effort. Twenty-three

Battle Creek winter-run Chinook Salmon carcasses from were recovered during the Sacramento River carcass survey and are included in the escapement estimate.

The CDFW has used the CJS model to estimate winter-run Chinook Salmon escapement since 2012. Due to its similarity to the Jolly-Seber model used previously, we consider escapement estimates from 2012-2021 to be directly comparable to those from 2003-2011. Figure 1, below, shows the Sacramento River winter-run Chinook Salmon spawner escapement estimates from 2003 to present. The reported total escapement estimate for 2021 is considered final, subject to revision if additional data becomes available after the date of this letter. Updated estimates can be found in the GrandTab spreadsheet which is updated if and when new information is received (https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=84381).

We look forward to further discussion and collaboration with National Marine Fisheries Service staff regarding the application of this information. Inquiries regarding the methodology and development of the estimates in this letter should be directed to Mr. Douglas Killam at Doug.Killam@wildlife.ca.gov or Ms. Erica Meyers at Erica.Meyers@wildlife.ca.gov.

Sincerely,

DocuSigned by:
Valerie Cook
96D42C58E092466...

Valerie Cook, Acting Fisheries Branch Chief

cc: Ms. Cathy Marcinkevage
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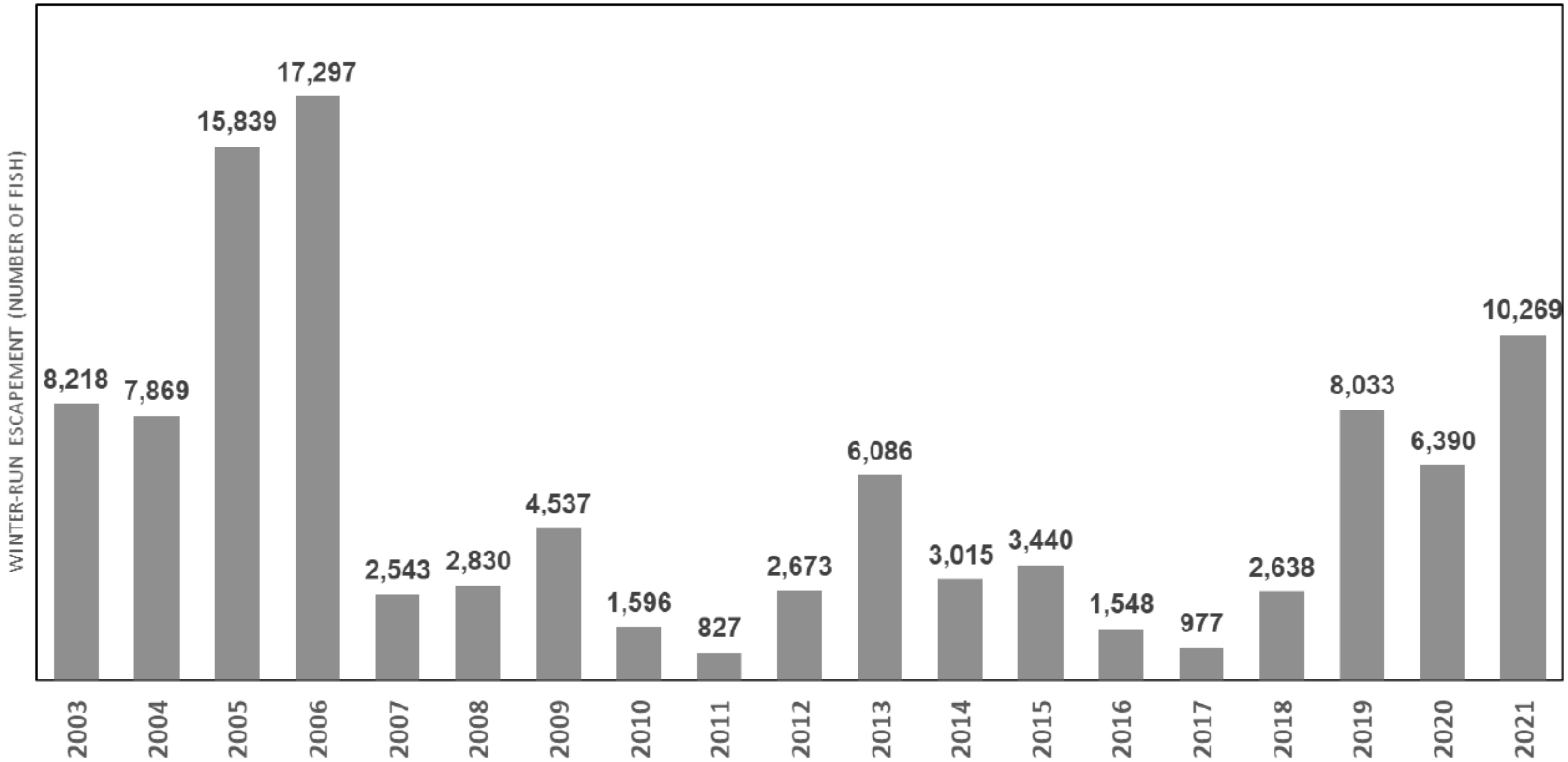

Figure 1. Estimated escapement of winter-run Chinook Salmon to the Upper Sacramento River Basin, 2003-2021. Data compiled from GrandTab (CDFW 2021; https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=84381). Data for 2009-2021 are preliminary and subject to change.

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GAVIN NEWSOM, Governor
CHARLTON H. BONHAM, Director

January 14, 2022

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Dr. Brooke Jacobs
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FINAL WINTER-RUN JUVENILE PRODUCTION ESTIMATE (JPE) FOR BROOD YEAR 2021

Dear Mr. Yip and Dr. Jacobs:

In 2013, the Interagency Ecological Program's Winter-Run Chinook Salmon Project Work Team (Winter-Run PWT) recommended that the National Marine Fisheries Service (NMFS) Juvenile Production Estimate (JPE) be revisited annually and updated as needed with any new or improved information. The annual JPE is used to calculate loss thresholds for Long-Term Operation of the Central Valley Project and the State Water Project, as described in the NMFS Biological Opinion, No. WRCO-2016-00069 (2019 NMFS BiOp) and required by CDFW Incidental Take Permit No. 2081-2019-066-00 (2020 ITP). A subgroup of the Winter-Run PWT met four times in December 2021 to review and update the factors used to calculate the brood year (BY) 2021 JPE, and to develop recommended draft winter-run JPE for BY 2021. The final JPE recommendation includes data through December 31, 2021 and was approved at the Winter-Run PWT meeting on January 14, 2022. The Winter-Run PWT's recommendations for the BY 2021 winter-run Chinook Salmon JPE are described below.

<u>JPE Recommendations</u>

The Winter-Run PWT identified several factors in calculating the JPE that we advise be continued or updated for BY 2021. We considered one method for forecasting natural-origin JPE—The "Method 2" approach used for the BY 2019 and BY 2020 JPEs and described in O'Farrell et al. (2018). The data inputs for the calculations include estimates of the following parameters for calculating JPE for natural-origin BY 2021 winter-run Chinook Salmon ($JPE_{Natural}$) (Figure 1):

1) Number of winter-run fry equivalents passing Red Bluff Diversion Dam (RBDD)(JPI_{Fry})
2) Survival rate of natural-origin fry to smolts ($Survival_{Fry\text{-}to\text{-}Smolt}$)
3) Survival rate of smolts from RBDD to Delta entry (defined as Sacramento at the I-80/I-50 Bridge) ($Survival_{Smolt}$)

Hatchery Release JPE Recommendations

Additionally, we used the number of winter-run hatchery smolts expected to be released from Livingston Stone National Fish Hatchery (LSNFH) in February 2022 ($N_{Hatchery}$) and their predicted survival rate ($Survival_{HatcherySmolt}$) to estimate a JPE of hatchery-origin winter-run juveniles in the Delta ($JPE_{Hatchery}$) (Figure 1). We present the data inputs used in the calculations in Table 1 and describe each in the sections below.

For the second year in a row, we also include estimates of hatchery-origin winter-run smolts released in Battle Creek as part of the "Jumpstart" reintroduction ($N_{BCJumpstart}$), their survival ($Survival_{BCJumpstart}$), and a forecast of the number entering the Delta ($JPE_{BCJumpstart}$). Although there was natural spawning in Battle Creek in 2021, we do not differentiate naturally produced juveniles from Battle Creek from Sacramento River juveniles, and both are included in the Juvenile Production Index (JPI_{Fry} or JPI).

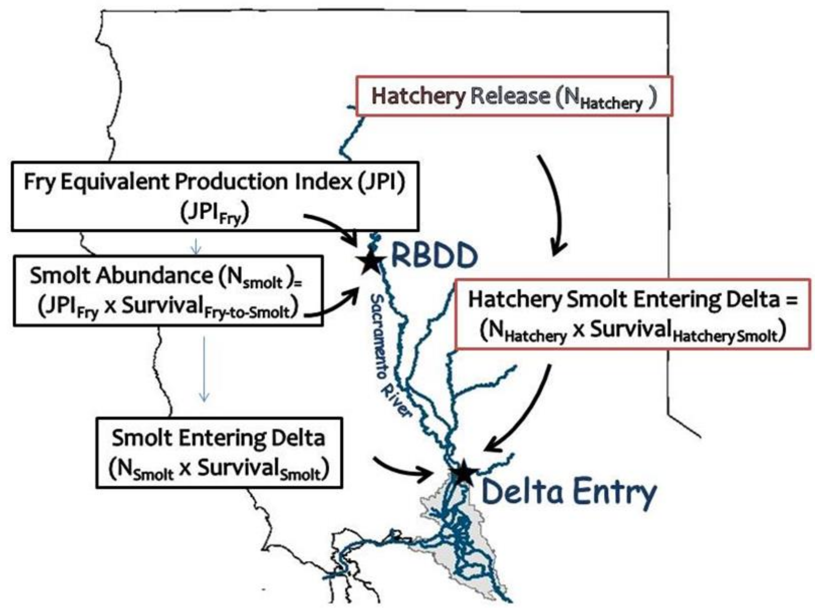


Figure 1. Location and formulas recommended for use in the JPE for the natural-origin (black boxes) and hatchery-origin (red boxes) components of the winter-run population estimated for BY 2021. Hatchery JPEs are estimated for hatchery releases from Livingston Stone National Fish Hatchery into the Sacramento River ($N_{Hatchery}$) and for the Battle Creek Jumpstart hatchery releases into Battle Creek (not shown).

Winter-Run JPE Methods for 2021-2022

The Winter-Run PWT focused on a single method for forecasting the JPE for BY 2021, as was done for BY 2020. This method was recommended in O'Farrell et al. (2018) and was the chosen method for BY 2019. It is the opinion of the Winter-Run PWT that this method represents the best available science for estimating an annual JPE given currently available data.

Juvenile Production Index - For the BY 2021 JPE, the Winter-Run PWT continues to recommend using the JPI, which is based on an estimate of fry equivalents at RBDD. The JPI has been used in the calculation since 2014 and better represents the response of fish to annual environmental conditions during spawning, egg incubation, and outmigration, as compared to the long-term average egg-to-fry survival rate used in the JPE prior to 2014. This is of particular

importance this year, as the JPI approach at least partially accounts for lower than average egg-to-fry survival in naturally spawned winter-run Chinook Salmon expected for BY 2021 due to thiamine deficiency in spawners and temperature-related mortality during egg incubation.

There are two updates worth noting about the winter-run Chinook Salmon JPI estimate this year. The first update is to the trap efficiency model employed in 2021. In response to changes in river channel geometry and juvenile trap configurations, USFWS updated the least-squares regression model used to predict daily trap efficiency, which expands RST catch to estimate the JPI. The new model uses data from efficiency trials conducted between 2018 and 2021 using natural-origin fall- and winter-run Chinook Salmon (n=32 trials; B. Poytress, USFWS, pers. comm.) and incorporates 13 trials conducted under the new trap configuration (four 5-ft traps and one 8-ft trap). Due to low catches of naturally produced winter-run Chinook Salmon in 2021, a single efficiency trial was conducted in Fall 2021. That trial has not yet been incorporated into the 32-trial model, but it fell within the 90 percent prediction interval of the current model, which supports use of the currently active model for winter-run Chinook Salmon in 2021.

The second difference in the 2021 JPI estimate was the need to interpolate passage data for 2 unsampled days during an unprecedented storm and runoff event in October when juvenile traps at RBDD could not safely operate. Juvenile capture during that time was interpolated using the weekly mean, which is the standard procedure (as described in Voss and Poytress 2020). Because the data gap occurred during the season's largest increase in flow, which oftentimes triggers increased juvenile migration (Poytress et al. 2014), the JPI may underestimate juvenile passage during that period.

Fry-to-Smolt Survival - The Winter-Run PWT recommends the continued inclusion of a fry-to-smolt survival factor ($\text{Survival}_{\text{Fry-to-Smolt}}$). This is necessary because the available survival estimates between RBDD and the Delta are based on releases of acoustically telemetered smolts, which have a higher survival rate than fry. Without this factor, the survival rate from fry to smolts is assumed to be 1.00, which is unrealistic. The same factor is used to adjust juvenile passage at RBDD to fry equivalents, based on the peak of fry catch at RBDD (generally in October) and the smolt life-stage at RBDD for naturally produced winter-run Chinook Salmon.

The Winter-Run PWT recommends the fry-to-smolt survival rate forecasting method developed by O'Farrell et al. (2018), which uses recent winter-run Chinook Salmon survival data and is updated with new survival data annually. Incorporating updated survival rate estimates, this method results in a winter-run Chinook Salmon fry-to-smolt survival rate of 0.4429 for BY 2021. The team recommends using this forecasting method to estimate fry-to-smolt survival in calculations of JPE and updating the fry equivalent multiplier to 2.258 (the factor 2.258 is the inverse of 0.4429). It is the opinion of the Winter-Run PWT that these updated values, which are based on peer-reviewed methodologies and more recent winter-run Chinook Salmon data, improve the JPE forecast compared to values used prior to 2019.

Fry Production - The JPI seasonal estimate of fry equivalents using the 0.4429 fry-to-smolt survival rate was 773,439 as of December 31, 2021 (week 52; B. Poytress, USFWS, personal communication). The value through December 31 accounts for approximately 96.90 percent of annual winter-run passage at RBDD based on data collected from 2002 to 2020. Including an interpolation of the remaining 3.10 percent to account for the remainder of BY 2021, the total BY 2021 estimate is 798,183 fry equivalents (Table 1). This value accounts for in-season winter-run genetic corrections, which have a minimal effect on the estimate. With this estimate of fry production at RBDD, the estimated egg-to-fry survival is calculated to be 0.0256 (Table 1).

Table 1 – Reported population estimates and survival factors for brood year 2021

(Factors used in the JPE calculations and the resulting JPEs are shown in bold.)

Component	Natural	Hatchery
Total Sacramento River escapement[1]	9,956	
Adult female estimate (AFE)[2]	6,199	
AFE minus pre-spawn mortality[3] (5.5%) ($N_{Spawners}$)	5,860	
Average fecundity[4] (AF)	5,312	
Total eggs	31,128,320	
Estimated egg-to-fry survival rate based on JPI at RBDD/Total eggs[5]	0.0256	
Fry equivalents of juvenile production at RBDD (JPI or JPI_{Fry})[6]	**798,183**	
Fry-to-smolt survival ($Survival_{Fry\text{-}to\text{-}Smolt}$)[7]	**0.4429**	
Number of smolts at RBDD	353,515	
Estimated smolt survival term: RBDD to Delta ($Survival_{Smolt}$)[8]	**0.3537**	
Total natural production entering the Delta (JPE)	**125,038**	
JPE 95 percent confidence interval	59,064 – 191,013	
LSNFH Hatchery release ($N_{Hatchery}$)[9]		**537,771**
Survival rate from release to Sacramento ($Survival_{HatcherySmolt}$)[10]		**0.2818**
Total LSNFH production entering the Delta		**151,544**
Battle Creek Hatchery release ($N_{BCJumpstart}$)[11]		**139,000**
Survival rate from release to Sacramento ($Survival_{BCJumpstart}$)[12]		**0.0526**
Total Jumpstart production entering the Delta		**7,311**

1/ Total Sacramento River in-river escapement from CDFW Cormack-Jolly Seber (CJS) model includes natural- and hatchery-origin winter-run Chinook Salmon, but not hatchery fish retained for brood stock at LSNFH.

2/ The number of adult females is derived from carcass surveys on the Sacramento River. Naturally spawning winter-run Chinook Salmon in Battle Creek are not included.

3/ Pre-spawn mortality was estimated from carcass surveys of females (Doug Killam, CDFW, pers. comm.).

4/ Preliminary (subject to change) average number of eggs per female from 118 female fish spawned at LSNFH (Kaitlin Gooding, USFWS pers. comm.).

5/ Back calculated survival between estimated eggs laid in-river and fry production estimates at RBDD based on numbers of fry equivalents (JPI) using the 0.4429 fry-to-smolt survival rate estimate based on method described in O'Farrell et al. (2018).

6/ Preliminary number of fry equivalents estimated on December 31, 2021 plus 3.1% interpolation to account for remainder of estimated passage for the 2021 brood year at RBDD; using 0.4429 fry-to-smolt survival rate estimate (Bill Poytress, USFWS, pers. comm.). This estimate includes and does not differentiate between the number of fry equivalents outmigrating from Battle Creek and the Sacramento River.

7/ Estimate of fry-to-smolt survival rate based on O'Farrell et al. (2018), updated using data from BY 1998-2016.

8/ Variance-weighted mean survival rate of acoustically tagged hatchery winter-run Chinook Salmon from 2013 to 2021 between RBDD and I-80/Tower Bridge in Sacramento (based on O'Farrell et al. 2018). Survival is estimated from the Salt Creek receiver site, located 3 miles downstream of RBDD, to estimate survival from RBDD for natural-origin smolts.

9/ Estimated LSNFH production release as of December 15, 2021 (100% tagged and adipose clipped).

10/ Variance-weighted mean survival rate of acoustically tagged hatchery winter-run Chinook Salmon from 2013 to 2021 between release location and I-80/Tower Bridge in Sacramento (based on O'Farrell et al. 2018).

11/ Estimated Battle Creek Jumpstart release as of January 14, 2022 (100% tagged and marked).

12/ Variance-weighted mean survival rate of acoustically tagged hatchery winter-run Chinook Salmon from 2019 to 2021 between release location in North Fork Battle Creek and I-80/Tower Bridge in Sacramento (based on O'Farrell et al. 2018). The survival rate of 64 fish on released on May 18, 2020 was not included in this calculation because fish size and environmental conditions did not represent expected conditions during the BY 2021 winter release. The change in survival to 0.0526 from 0.0519 in the draft letter issued December 31, 2021 reflects a correction to the weights assigned to each survival rate; although the estimate in the draft letter excluded the May 2020 release survival rate, the variance-based weights had not yet been adjusted to exclude that release.

Natural-origin Smolt Survival - To estimate survival of natural origin winter-run Chinook Salmon smolts from RBDD (i.e., Salt Creek) to the Delta (i.e., Sacramento at the I-80/I-50 Bridge)(Survival$_{Smolt}$), the Winter-Run PWT recommends using the variance-weighted mean of survival estimates from acoustically tagged LSNFH smolts released in 2013–2021, as described in O'Farrell et al. (2018). This calculation is updated each year to incorporate survival and variance estimates from the previous year and uses the Cormack-Jolly-Seber model, which accounts for variation in detection probabilities. The estimated annual survival rate using this method is 0.3537. Note that the release-specific survivals for all years were recalculated for this year's estimate based on an updated filtering algorithm (Danner and Ammann, 2021).

Hatchery Smolt Survival – To estimate survival of hatchery-produced winter-run Chinook Salmon released in the Sacramento River near Redding (Survival$_{HatcherySmolt}$), we recommend using the variance-weighted mean of 2013–2021 survival rates from the LSNFH release point to the Delta. This survival rate is 0.2818. For hatchery-produced winter-run released in North Fork Battle Creek (Survival$_{BCJumpstart}$), we recommend using the variance-weighted mean of 2019–2021 survival rates from the Battle Creek release point to the Delta (excluding the May 2020 release because fish size and environmental conditions did not represent expected conditions during the BY 2021 winter release). This survival rate is 0.0526. Because both release points of hatchery fish are upstream of RBDD, the overall survival to the Delta is lower compared to the survival applied to natural-origin smolts. As for natural-origin smolt survival, these estimates of hatchery smolt survival use the Cormack-Jolly-Seber model to account for variation in detection probabilities and are updated annually to incorporate survival and variance estimates from the previous year.

Discussion on low estimated egg-to-fry survival for BY 2021

The approach described above allows us to back-calculate egg-to fry survival based on estimates of the number of successful female spawners (N$_{Spawners}$), average female fecundity (AF), and JPI, as described under "Fry Production" and in Equation 1. This calculation can be a useful metric to compare to average or expected survival in order to identify mortality occurring during egg incubation and fry emergence. Using this equation, estimated BY 2021 egg-to-fry survival for winter-run Chinook Salmon is 0.0256. The two primary factors contributing to low egg-to-fry survival in BY 2021 are thought to be temperature dependent mortality and thiamine deficiency complex.

Equation 1:

$$Survival_{Egg-to-Fry} = \frac{JPI_{Fry}}{N_{Spawners} \times AF}$$

Winter-run Chinook Salmon in 2021 spawned during one of the warmest and driest years on record, and Sacramento River water temperatures during the majority of the incubation period exceeded limits for successful egg incubation. Using the Martin et al. (2017) model, NMFS estimated mean annual temperature dependent mortality of winter-run Chinook Salmon eggs at 75 percent (25–75% confidence interval of 64–81%), based on measured water temperatures and mapped winter-run Chinook Salmon spawning locations in the Sacramento River in 2021 (SWFSC, 2021).

Additional early life stage mortality was likely due to thiamine deficiency complex syndrome, thought to be the result of shifts in marine forage fish species off the coast of California. Thiamine concentrations in egg samples from 30 females spawned at LSNFH in 2021 showed 83 percent of females with thiamine low enough where some fry mortality would be expected (T. Lipscomb, USFWS, pers. comm.). Any thiamine deficiency impacts manifested in egg viability or early fry stages will lead to a reduced JPI compared to what would have been observed absent thiamine deficiency impacts. USFWS had only one observation of abnormal fry behavior at the RBDD rotary screw traps (B. Poytress, USFWS, pers. comm.), suggesting that mortality caused by thiamine deficiency occurred primarily upstream of RBDD, though there may be latent impacts to young-of-year winter-run Chinook Salmon downstream of RBDD that cannot be estimated based on information available this year. The assumption that most mortality would occur prior to outmigration is consistent with observations at Central Valley hatcheries, where mortality and behavioral abnormalities associated with thiamine deficiency in hatchery-origin juveniles were documented soon after hatch. Survival studies of untreated fish would be necessary to understand lower survival due to latent effects of thiamine deficiency.

Uncertainty exists within all three of the variables used to calculate an estimate of egg-to-fry survival. Female spawners and fecundity estimates are not used in the JPE calculation, and their uncertainty is not quantified during JPE development. Uncertainty in the JPI is quantified, and it is a factor considered in the JPE calculation and in the back-calculation of egg-to-fry survival. For 2021, the nonoperation of the juvenile traps at RBDD for two days during a substantial storm event in October, and potential underestimate of passage during that event for the JPI, may contribute to the relatively low estimate of egg-to-fry survival. Standard methods used to interpolate juvenile fish passage data for unsampled days (see Voss and Poytress 2020) during the October flow event likely resulted in a slight negative bias to the juvenile passage estimates for those days. However, the impact of those two interpolated days on the total JPI calculated for the entire BY 2021 outmigration season is likely captured within the uncertainty (confidence intervals) of the 2021 JPI. The current range of uncertainty around the preliminary point estimate JPI would result in an egg-to-fry survival estimate of between 0.0166 and 0.0353.

It is unknown how much each of these factors may be contributing to the low estimated egg-to-fry survival for BY 2021, but there are ongoing efforts to better understand the contribution of each and any interactions between them. It is important to note that because the method used to calculate the JPE uses the JPI approach, any uncertainty about the mortality does not affect the JPE. Uncertainty in the JPE as a result of uncertainty in the JPI is captured in the 95 percent confidence intervals shown in Table 1.

Winter-Run PWT Recommended Method for BY 2021

The Winter-Run PWT recommends the previously described inputs and the following equations be used for estimating the BY 2021 natural-origin (Equation 2) and hatchery-origin (Equations 3 and 4) JPE:

Equation 2:

$$\begin{aligned} JPE_{Natural} &= JPI_{Fry} \times Survival_{Fry-to-Smolt} \times Survival_{Smolt} \\ &= 798{,}183 \times 0.4429 \times 0.3537 = 125{,}038 \end{aligned}$$

Equation 3:

$$JPE_{Hatchery} = N_{Hatchery} \times Survival_{HatcherySmolt}$$

$$= 537{,}771 \times 0.2818 = 151{,}544$$

Equation 4:

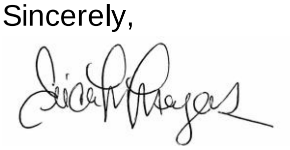
$$JPE_{BCJumpstart} = N_{BCJumpstart} \times Survival_{BCJumpstartSmolt}$$

$$= 139{,}000 \times 0.0526 = 7{,}311$$

It is the opinion of the Winter-Run PWT that this method represents the best available science for estimating a JPE given currently available data. It accounts for detection probabilities and quantifies uncertainty associated with estimates of JPI_{Fry} and smolt survival rates, which are used to develop the 95 percent confidence intervals for the JPE forecast. Because it does not capture process error, or the variation in true survival rates from year to year, these confidence intervals likely underestimate the uncertainty in the JPE forecast. We acknowledge that this method still has considerable uncertainty, and that confidence intervals may have limited utility to water managers under the current management setting. However, there is uncertainty with any forecast method for a JPE, and we believe there is value in quantifying and reporting that uncertainty.

It is the opinion of the Winter-Run PWT that this recommendation is the best information currently available from which to derive a JPE and the best method for arriving at estimates. We conclude that this analysis and these technical recommendations from the Winter-Run PWT will establish the most accurate forecast of JPE for use in the 2022 water year at the Central Valley Project and State Water Project export facilities.

Sincerely,



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